Technical Notes on the Standardized Transfusion Ratio (STrR)

For the Dialysis Facility Reports

July 2021

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1 Introduction

The Standardized Transfusion Ratio (STrR) for all adult Medicare dialysis patients in Table 8 of the Dialysis Facility Reports (DFR) is designed to reflect the number of eligible red blood cell transfusion events occurring in patients dialyzing at a facility, relative to the number of eligible transfusions that would be expected under a national norm, after accounting for the patient characteristics within each facility. Specifically, the STrR is calculated as the ratio of two numbers: the numerator ("observed") is the actual number of transfusion events over a year period, and the denominator ("expected") is the number of transfusion events that would be expected if patients at that facility experienced transfusion events at the national average rate for patients with similar characteristics. As is evident from the preceding description, the STrR represents the transfusion analog of the Standardized Mortality Ratio (SMR) and Standardized Hospitalization Ratio (SHR) used to quantify a facility's mortality and hospitalization experience relative to the national average.

To compute a facility's "expected" count, we utilize a regression model that contains outcome-related factors or covariates, such as patient age, diabetes, duration of ESRD, nursing home status, BMI at incidence, comorbidities at incidence, and calendar year, etc.

The degree to which the facility's STrR varies from 1.00 measures the performance of the facility in reducing overall transfusions. For example, a facility's STrR=1.30 indicates that the facility's covariate-adjusted transfusion rate exceeds the national transfusion rate by 30%, e.g. 260 observed transfusion events versus 200 expected. Similarly, an STrR=0.90 would indicate that the facility's transfusion rate is 10% below the national transfusion rates (e.g., 180 transfusion events observed versus 200 expected). An STrR=1.00 would indicate that the facility's overall transfusion rate equals the national transfusion rate. In the DFR, we also report STrR for a given region (i.e., state, network). A region's STrR is calculated as the ratio of the total number of observed transfusions among patients from that region, to the expected number of transfusions for that region's patients adjusted for the patient characteristics described below. The regional STrRs are provided for comparison purposes, so that each facility's STrR can be compared to the STrR for the region in which it is located.

The document is organized as follows. Section 2 gives required administrative details. Section 3 gives the identification method of transfusion events. In Section 4, we detail a two-stage modeling approach for computing the expected transfusions given patients' characteristics. Section 5 gives a detailed description for computing p-values and confidence intervals, which accounts for possible uncertainty or random variations that may be beyond the control of the facilities. We give some final remarks in Section 6.

2   **Assignment of Patients to Facilities for the STrR Calculation**

As patients can receive dialysis treatment at more than one facility in a given year, we assign each patient day to a facility (or no facility, in some cases) based on a set of conventions below, which largely align with those for the Standardized Mortality Ratio (SMR) and Standardized Hospitalization Ratio (SHR). We detail patient inclusion criteria, facility assignment and how to count days at risk, all of which are required for the risk adjustment model.

2.1   **General Inclusion Criteria for Dialysis Patients**

Though a patient's follow-up in the database can be incomplete during the first 90 days of ESRD therapy, we only include a patient's follow-up into the tabulations after that patient has received chronic renal replacement therapy for more than 90 days. Thus, transfusions, hospitalizations, mortality and survival during the first 90 days of ESRD do not enter into the calculations. This minimum 90-day period also assures that most patients are eligible for Medicare, either as their primary or secondary insurer. It also excludes from analysis patients who die or recover during the first 90 days of ESRD.

In order to exclude patients who only received temporary dialysis therapy, we assigned patients to a facility only after they had been on dialysis there for at least 60 days. This 60 day period is used any time a patient begins therapy at a new facility whether the patient transferred from another facility, started ESRD for the first time, or returned to dialysis after a transplant. That is, transfusion events during the first 60 days of dialysis at a facility do not affect the STrR of that facility.

2.2   **Identifying Facility Treatment Histories for Each Patient**

For each patient, we identified the dialysis provider at each point in time using a combination of Medicare dialysis claims, the Medical Evidence Form (Form CMS-2728), and CROWNWeb. Starting with day 91 of ESRD, we determined facility treatment histories for each patient, and then listed each patient with a facility only once the patient had been treated there for 60 days. When a patient transferred from a facility, the patient remained assigned to it in the database for 60 days. This continued tabulation of the time at risk for 60 days after transfer from a facility attributes to a facility the sequelae of treatment there, even when a patient was transferred to another facility (such as a hospital-based facility) after his or her condition worsened.

Additionally, patients for whom the only evidence of dialysis treatment is the existence of Medicare claims were considered lost to follow-up and removed from a facility's analysis one year following the last claim, if there was no earlier evidence of transfer, recovery, or death. If evidence of dialysis re-appeared, the patient was entered into analysis after 60 days of continuous therapy at a single facility. All CROWNWeb records noting continuing dialysis were extended until the appearance of any evidence of recovery, transfer, or death. Periods of lost to follow-up were not created in these cases since the instructions for CROWNWeb only require checking patient data for continued accuracy, but do not have a requirement for updating if there are not any changes

For STrR, since the transfusion ratio should ideally include only patients whose Medicare billing records include all transfusions for the period. To achieve this goal, we require that patients reach a certain level of Medicare-paid dialysis bills to be included in transfusion statistics, or that patients have Medicare inpatient claims during the period. For the purpose of analysis, each patient's

follow-up time is broken into periods defined by time since dialysis initiation. For each patient, months within a given period are included if that month in the period is considered 'eligible'; a month is deemed eligible if it is within two months of a month having at least $1,200 of Medicare-paid dialysis claims or at least one Medicare inpatient claim. Additionally, months identified as having Medicare Advantage according to the Medicare Enrollment Database (EDB) coverage were excluded. In setting this criterion, our aim is to achieve completeness of information on transfusions for all patients included in the years at risk.

Beyond that, the STrR, however, has more exclusions to the eligible patient population. Transfusions associated with a transplant hospitalization are excluded as they mark a transition of care from the dialysis facility to a transplant team. Patients are also excluded if they have a Medicare claim (Part A inpatient, home health, hospice, and skilled and nursing facility claims; Part B outpatient and physician supplier) for hemolytic and aplastic anemia, solid organ cancer (breast, prostate, lung, digestive tract and others), lymphoma, carcinoma in situ, coagulation disorders, multiple myeloma, myelodysplastic syndrome and myelofibrosis, leukemia, head and neck cancer, other cancers (connective tissue, skin, and others), metastatic cancer, or sickle cell anemia within one year of their patient at risk time. These prevalent comorbidities define a sub-population of patients who are at increased risk of blood transfusions. A complete list of ICD-9/ICD10 codes used for these exclusions is available at https://dialysisdata.org/content/dialysis-facility-report-methodology/DFR_Codes.pdf. Once a patient is diagnosed with one of these comorbidities, a patient's time at risk is included only after a full year free of claims that list any diagnosis on the exclusions list.

2.3   Days at Risk for Medicare Dialysis Patients

After patient treatment histories are defined as described above, periods of follow-up in time since ESRD onset are created for each patient. In order to adjust for duration of ESRD appropriately, we define 6 time intervals with cut points at 6 months, 1 year, 2 years, 3 years and 5 years. A new time period begins each time the patient is determined to be at a different facility, or at the start of each calendar year or when crossing any of the above cut points.

The number of days at risk in each of these patient-ESRD-year-facility time periods is used to calculate the expected number of transfusions for the patient during that period. The STrR for a facility is the ratio of the total number of observed transfusions to the total number of expected transfusions during all time periods at the facility.

3   Identification of Transfusion Events

The outcome for this measure is the risk adjusted facility level transfusion event count among adult Medicare eligible dialysis patients.

Our method for counting transfusion events relies on a conservative counting algorithm and, because of the way transfusion information is reported in Medicare claims, we use different rules for counting transfusion events, depending on whether or not the event occurs in the inpatient setting, or an outpatient setting. The most common way that events are reported on claims is by reporting a revenue center, procedure, or value code (inpatient claims) or for outpatient claims, reporting Healthcare Common Procedure Coding System (HCPCS) codes with at least one revenue center codes. A complete list of ICD-9/ICD10 codes used for the transfusion identification is available at https://dialysisdata.org/content/dialysis-facility-report-methodology/DFR_Codes.pdf.

One "transfusion event" is counted per inpatient claim if one or more transfusion-related revenue center, procedure or value codes are present. We only count a single transfusion event for an inpatient claim regardless of the number of transfusion revenue center, procedure and value codes reported so that the number of discrete events counted is the same whether the claim indicates 1 unit of blood or multiple units of blood. This results in a very conservative estimate of blood transfusions from inpatient claims.

Transfusion events are not common in outpatient settings, but similar rules apply. One or more transfusion-related HCPCS codes with at least one transfusion-related revenue center codes, or one or more transfusion-related value codes listed on an outpatient claim are counted as a single transfusion event regardless of the number of units of blood recorded. In other words, 3 units of blood would be counted as a single transfusion event.

4   Model for Calculating Expected Transfusion

The denominator of the STrR stems from a proportional rates model (Lawless and Nadeau, 1995; Lin et al., 2000; Kalbfleisch and Prentice, 2002). This is the recurrent event analog of the well-known proportional hazards or Cox model (Cox, 1972; Kalbfleisch and Prentice, 2002). To accommodate large-scale data, we adopt a model with piecewise constant baseline rates (e.g. Cook and Lawless, 2007) and the computational methodology developed in Liu, Schaubel and Kalbfleisch (2012). Model coefficients and baseline survival curves are available for download here: https://dialysisdata.org/content/dialysis-facility-report-methodology/STrRModelInfo_0.xls.

The modeling process has two stages. At **stage I**, a stratified model is fitted to the national data with piecewise-constant baseline rates and stratification by facility. Specifically, the model is of the following form

$$Pr(\text{transfusion on day } t \text{ given covariates } X) = r_{0k}(t)exp(\beta'X_{ik})$$

where X_{ik} is the vector of covariates for the (i,k)th patient and β is the vector of regression coefficients. The baseline rate function $r_{0k}(t)$ is assumed specific to the kth facility, which is assumed to be a step function with break points at 6 months, 1 year, 2 years, 3 years and 5 years since the onset of dialysis. This model allows the baseline transfusion rates to vary between strata (facilities), but assumes that the regression coefficients are the same across all strata; this approach

is robust to possible differences between facilities in the patient mix being treated. The stratification on facilities is important in this phase to avoid bias due to possible confounding between covariates and facility effects.

The patient characteristics X_{ik} included in the stage I model are age (18-24 years old, 25-44 years old, 45-59 years old, 60-74 years old, or 75+ years old), cause of ESRD (diabetes or other), nursing home status, BMI at incidence, individual comorbidities at incidence reported on the Medical Evidence Form (CMS-2728), calendar year, and two-way interaction terms of age * cause of ESRD and duration of ESRD * cause of ESRD. Duration of ESRD is categorized as 91 days-6 months, 6 months-1 year, 1-2 years, 2-3 years, 3-5 years, or 5+ years as of the period start date. Nursing home status is included as two categorical terms: one to indicate a long-term stay ($\geq$90 days), and one to indicate a short-term stay (1-89 days) in the previous 365 days from the first day of time period at risk. BMI is included as a categorical variable indicating being underweight, normal, overweight, or obese according to the World Health Organization criteria (WHO, 2020). The missing BMI values are imputed as obese. A categorical indicator variable is included as a covariate in the stage I model to flag records with missing values for cause of ESRD. This variables has a value of 1 if the patient is missing the corresponding piece of information and a value of 0 otherwise. Another two categorical indicator variables are included to flag records with having no comorbidities and having at least one comorbidity at incidence reported on the Medical Evidence Form. These variables have a value of 1 if the patient is having no comorbidities or having at least one comorbidity and a value of 0 otherwise.

At **stage II**, the relative risk estimates from the first stage are used to create offsets and an unstratified model is fitted to obtain estimates of an overall baseline rate function. That is, we estimate a common baseline rate of transfusions, $r_0(t)$, across all facilities by considering the model

$$\textbf{\textit{Pr(transfusion on day t given covariates X) = }} r_0(t) \, R_{ik},$$

where $R_{ik} = \exp(\boldsymbol{\beta}'X_{ik})$ is the estimated relative risk for patient i in facility k estimated from the stage I. In our computation, we assume the baseline to be a step function with 6 unknown parameters, $\alpha_1, \ldots, \alpha_6$, to estimate. These estimates are used to compute the expected number of transfusions given a patient's characteristics.
Specifically, let t_{iks} represent the number of days that patient i from facility k is under observation in the sth time interval with estimated rate α_s. The corresponding expected number of transfusions in the sth interval for this patient is calculated as

$$E_{iks} = \alpha_s \, t_{iks} \, R_{ik} \ .$$

It should be noted that $\textbf{t}_{\textbf{iks}}$ and hence $\textbf{E}_{\textbf{iks}}$ can be 0 if patient i from facility k is never at risk during the sth time interval. Summing the $\textbf{E}_{\textbf{iks}}$ over all 6 intervals and all $\textbf{N}_{\textbf{k}}$ patients in a given facility, k, gives

$$E = \sum_{i=1}^{N} \sum_{s=1}^{6} E_{iks} = \sum_{i=1}^{N} \sum_{s=1}^{6} \alpha_s \, t_{iks} \, R_{ik},$$

which is the expected number of transfusions during follow-up at that facility.

Let **O** be the observed total number of transfusions at this facility. The STrR for transfusions is the ratio of the observed total transfusions to this expected value, or

$$\textbf{STrR = O/E} \ .$$

4.1   Missing Data

Patients with missing data are not excluded from the model. For the purposes of calculation, the missing BMI values are imputed as obese. Missing values for cause of ESRD are replaced with the other/unknown category. No patients were missing age, sex, or date of first ESRD treatment. Indicator variables identifying patients with missing values for cause of ESRD, and comorbidities at incidence (missing CMS-2728) are also included as covariates in the model.

5   Calculation of STrR P-Values and Confidence Intervals

A p-value assesses the probability that the facility would experience a number of transfusions more extreme than that observed if the null hypothesis were true; accounting for each facility's patient mix. To do this, a z-score is first calculated using the estimate and standard error for each facility using the method of generalized estimating equations (GEE; Liang & Zeger, 1986). Specifically, the transfusion rate (or, equivalently: the mean transfusion count, given the exposure) was assumed to follow a multiplicative model and a robust (sandwich) standard error was used. The use of robust standard errors has been advocated for modeling recurrent events (i.e., multiple events per subject) by several previous authors; e.g., Lawless & Nadeau (1995); Lin, Wei, Yang & Ying (2000); Cai & Schaubel (2004). For each facility, the Z-score was computed as the facility's log(STrR), divided by its standard error. Since log(STrR) is undefined for facilities with 0 transfusions, the Z-score in such cases was computed as (STrR-1), divided by a standard error estimate (sandwich estimator) for STrR.

To account for the over dispersion in the z-scores, as used in Standardized Hospitalization Ratio (NQF #1463 http://www.qualityforum.org/QPS/1463), we use robust estimates of location and scale based on the center of the z-scores (by fitting robust regression on z- scores) and derive normal curves that more closely describes the z-score distribution. This new distribution is referred to as the "empirical null hypothesis" (Efron, 2004) and provide references for assessing the extent to which a given facility's outcomes are extreme in comparison with other facilities. We then use the mean and standard deviation from the empirical null distribution of the STrR z-scores to calculate the p-value for classifying facility performance.

5.1   Example

The uncertainty or confidence intervals are obtained by applying the following steps:
- From the general linear model we obtain the natural log of the STrR (ln STrR) as well as its standard error, (SE). From the empirical null, we obtain a mean (μ) and a standard deviation (σ). The 95% uncertainty interval for the 'true' log standardized transfusion ratio for this facility is

$$\ln \text{STrR} - \mu * \text{SE} \pm 1.96 * \sigma * \text{SE}.$$

Note that 1.96 is the critical point from the standard normal distribution for a 95% interval.

- Exponentiating the endpoints of this interval gives the uncertainty interval for the true STrR.

For example, consider a hypothetical facility whose STrR is 0.927 for which ln STrR = -0.076 with corresponding standard error, SE = 0.118. This facility falls in a quartile where the empirical null has μ = -0.143 and σ = 1.479. The corresponding uncertainty interval for the log STrR is

$$-0.076 - (-0.143)*0.118 \pm 1.96 *0.118*1.479 = (-0.401, 0.283).$$

The 95% interval for the true STrR is then 0.67 to 1.33.

5.2   Flagging rules

For reporting purposes, we identify outlier facilities from amongst those with at least 10 patient-years at risk during the time period. If the 95% interval lies entirely above the value of 1.00 (i.e. both endpoints exceed 1.00), the facility is said to have outcomes that are "worse than expected". On the other hand, if the 95% interval lies entirely below the value 1.00, the facility is said to be "better than expected". If the interval contains the value 1.00, the facility is said to have outcomes that are "as expected".

6   Final Remarks

This document details the computation of STrR, designed to measure the performance of facilities in reducing transfusions. Our proposed methods are based on several statistical publications developed by the investigators of UM-KECC and have been tested in various settings. In general, the validity of any standardized measures largely depend on the validity of risk-adjustment models. As proper choices of risk adjusters are vital in the process, our practical principles lie in scientific relevance and caution of sequel. That is, we choose risk adjusters that are scientifically relevant to the outcome, while avoiding choosing those which may be affected by the quality of care.

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